THE

COMSTOCK LODE:

ITS CHARACTER,

AND THE PROBABLE MODE OF ITS CONTINUANCE IN DEPTH.

BY

FERDINAND BARON RICHTHOFEN, DR. PHIL.

(November 22d, 1865.)

SAN FRANCISCO:

PUBLISHED BY THE SUTRO TUNNEL COMPANY.

TOWNE AND BACON, PRINTERS.

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J.C. Branner
THE Feb-96

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TO THE

Board of Trustees of the Sutro Tunnel Co.

VIRGINIA, Nev., November 22d, 1865.

GENTLEMEN: In compliance with your request, I beg to submit the subjoined statement of my views in regard to the character of the Comstock vein and the probable mode of its continuance in depth, as well as the necessity of constructing a deep adit-level for the purpose of drainage and ventilation.

I have had, during my sojourn in the Pacific States, repeated opportunities of visiting the Washoe region, and have made its geology and the structure of the Comstock vein, the object of my careful investigation. In the course of my explorations, I have become more and more impressed with the necessity of securing the future profitable productiveness of the Comstock vein and the prosperity of a numerous population by the great work which you propose to execute, and for which few silver mines throughout the world offer greater inducements, while none can boast of equal facilities. I, therefore, cheerfully embrace the opportunity which you offer me, to aid in promoting an enterprise of lasting value, upon the execution of which depends the future of the mines on the Comstock vein.

Hoping sincerely that you may meet with success,

I remain, gentlemen,

Yours, very respectfully,

F. B. RICHTHOFEN.

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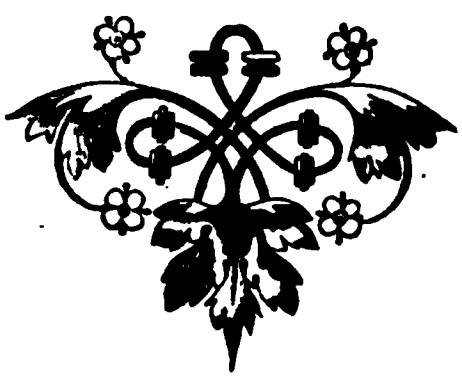

ON THE

CHARACTER OF THE COMSTOCK VEIN,

AND THE

PROBABLE MODE OF ITS CONTINUANCE IN DEPTH.

By Ferdinand Baron Richthofen.

The Comstock lode, in the State of Nevada, may be ranked among the richest and most productive metalliferous deposits which in historical time are on record in any part of the world; and, although but a short time has elapsed since its discovery, it adds considerably to the present production of silver. Its produce has been:

YEAR.	TOTAL.	SILVER.	GOLD.
1862.....	about $4,000,000	about $2,500,000	about $1,500,000
1863.....	" 12,000,000	" 8,000,000	" 4,000,000
1864.....	" 16,000,000	" 11,000,000	" 5,000,000
1865*.....	" 16,000,000	" 11,250,000	" 4,750,000
Total produce 1862 to 1865,...	$48,000,000	$32,750,000	$15,250,000

If it is considered that in 1854, since which time

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* The figures for this year, were arrived at by guess; the actual returns for the year 1865 have shown a production of little upwards of $15,000,000.

the annual production of silver in other parts of the world has not undergone great changes, the total amount of silver produced was, according to Prof. Whitney, $47,443,200, of which sum $7,864,000 came from European, and $39,451,200 from American mines, it will be seen that the produce of silver (deducting the gold) of the Comstock vein, in the last three years, was about twenty-three per centum of the entire amount furnished by all the silver mines in the world. It exceeds the aggregate produce of all European countries, and equals that of the entire Western coast of South America, which in 1854 was $11,099,200. The only country to which it is inferior, is Mexico. But it would, of course, be unfair to compare the produce of one single vein with that of the country which exceeds all others in the abundance of silver-bearing veins.

The extraordinary productiveness has made the Washoe-region more famous for its mineral wealth than many places where silver ores have been mined and extracted for centuries. It has attracted a numerous civilized population to a country, which before was sparcely inhabited by wandering Indian tribes, and which, by its desert character, seemed to debar forever human industry and arts; it has built cities in this desert, and roads across high mountain ranges, and at the present time accelerates the connection by steam of the Atlantic and Pacific coasts of America; it has created a new branch of mining in the Pacific States, which, through the discovery of the Comstock vein,

has assumed gigantic proportions all over the Great Basin; it has given successful employment to large amounts of capital, and rescued the trade of California from imminent decline at a time when the placer mines were rapidly decreasing in importance.

Yet, notwithstanding the achievement of such remarkable results in the space of a few years, the question arises, whether the mining interest of Washoe, the only source of wealth indeed which this country possesses, is going to decline and attain the end of a few years history, or whether it is going to last for a long time to come, and if so, by what means its future existence and greatness may be promoted? There are not a few, and among them men of prominent intellect and experience, who are of the opinion that the era of the productiveness of Washoe is fast approaching its end, the Comstock vein being a gash-vein terminating in depth in the shape of a wedge, and who, on the strength of this preconceived idea, would reject any means proposed for securing lasting profits. It is, therefore, a matter of no small importance, to investigate the nature of the Comstock vein, for the purpose of arriving at definite conclusions as to its true nature and the prospects of its further successful exploration.

It may be objected, that after only a few years of mining the true nature of a mineral deposit can hardly be understood. But it must be borne in mind that probably no mine ever fell, from the day of its discovery, into the hands of so enterprising and energetic a pop-

ulation as that engaged on the Comstock vein, and no metalliferous deposit ever was developed so fast, not even excepting the great Potosi mine in Bolivia. The amount of work done in Washoe would, under ordinary circumstances, at the slow rate at which mining is conducted in other countries, have required five or six times as many years for its execution.

Numerous facts of importance have been brought to light by these explorations, and these have to be collected and compared, in order to arrive at definite conclusions as to the character of the Comstock vein so frequently and bitterly discussed in the courts of Virginia City, and to solve satisfactorily many important problems, such as the following questions: Will the vein extend downwards to an indefinite depth? Will its metallic yield increase or decrease in depth, or will it remain stationary? What means have to be applied to make deep working profitable? Will the vein retain its dip in depth? etc. There is also considerable general interest connected with these researches, inasmuch as scarcely ever, since geology has taken its place among the inductive sciences, has opportunity been given for studying the character near the surface, of a metalliferous vein of equal magnitude, since almost every one had been worked to great depth before the practical use of such investigations began to be appreciated.

OUTLINES OF THE GEOLOGY OF WASHOE.

The range of the Washoe mountains, on which the Comstock vein is situated, is separated from the steep eastern slope of the Sierra Nevada by a continuous meridional depression marked by the deep basins of Truckee Valley, Washoe Valley, and Carson Valley. Its shape is irregular, though in general a direction from south to north may be traced in the summit range. South, it slopes gradually down to a smooth table-land, traversed from west to east by the Carson River flowing in a narrow crevice, beyond which the Washoe range continues in the more elevated Pine-Nut Mountains. Some peaks in the latter have an altitude of probably more than nine thousand feet. To the west the Washoe mountains descend rapidly and sink beneath the detrital beds of Washoe Valley and Truckee Valley, but are connected with the Sierra Nevada by two low granite ridges stretching, at right angles with its general course, across the northern and southern ends of Washoe Valley, and thus isolating its basin. To the north and east, the Washoe range passes into a very extensive mountainous region which is but little explored; while to the south-east it disappears abruptly below one of the middle basins of Carson River. The width of the entire range is not more than fourteen miles, while its length from north to south is not yet determinable, on account of the scanty knowledge we possess about the northern parts

of the country. The culminating point of the range is Mount Davidson, the elevation of which was determined by Professor J. D. Whitney as 7,827 feet. The altitudes of other places are: Virginia City, (B Street) 6,205 feet; Devil's Gate, 5,105 feet; while the basins to the west and south, have the following elevations: Washoe Lake, 5,006 feet; Carson City, 4,615 feet; Dayton, 4,490 feet; all according to barometrical measurement by Professor Whitney.

The summit range, which extends northerly and southerly from Mount Davidson, forms the water-shed; deep gulches, marking the intense eroding action of currents in former times, though now almost entirely dry, descend from it down to the basins.

The aspect of the Washoe mountains is exceedingly barren; so is the view from Virginia over the hilly country to the east. Yet, there is a remarkable grandeur and sublimity in it. The air is extraordinarily pure and transparent, so as to allow every gulch and declivity in the slope of mountains a hundred miles off to be distinguished. The eye wanders over an unbroken desert, where barren hills alternate with wide and sandy basins. There is no beauty in this scenery, but it has a strange charm; the constant enjoyment of the distant view is a redeeming feature of life in Virginia.

At the time of the discovery of the Comstock vein, the Washoe mountains are said to have been covered with scattered trees of the nut-pine and cedar.

But since then, they have been extirpated, and Virginia depends for its supply of wood and timber chiefly on the slope of the Sierra Nevada, which, down to the before-mentioned depression, is covered with a continuous forest. The enormous consumption of hewn timber in the mines is, however, rapidly bringing about the destruction of the better part of those forests, and the supply will soon have to be obtained from a greater and greater distance. It is almost unlimited on Truckee River, at thirty miles distance from Virginia, but this will only be made available by the construction of a railroad from that place to the mines.

The situation of Washoe in the westernmost part of the great basin, and immediately east of the steep eastern slope of the Sierra Nevada, causes it, in its geological features, to form an intermediate link between the structure of both of them, though it partakes far more of the diversified composition peculiar to the mountain ranges of the Great Basin. To the Sierra Nevada it is related by the metamorphism of its sedimentary formations, which farther east appear more regularly stratified and less altered. With both it has in common the considerable part which tertiary and post-tertiary eruptive rocks, partly of pure volcanic origin, play in its architecture. We mention in the following only the more important rocks.

Mount Davidson, the prominent central point, consists of *Syenite*, a granitic rock, which here is composed of two kinds of feldspar (orthoclase and oligo-

clase), hornblende in laminated prisms of greenish black color, some mica, and occasionally epidote, but no quartz. It is probably a continuation of the granitic axis of the Pine-Nut mountains, and forms with the *Metamorphic rocks*, which accompany it, the backbone of the Washoe mountains. The latter rocks join the syenite to the north and south, and are intersected by dykes of that rock, thereby proving its later origin. Lithologically, they exhibit a great variety; but they may be subdivided in three distinct groups, one of which is *of Triassic age*, and was first discovered by Prof. J. D. Whitney in Eldorada Cañon near Dayton; this is the most recent group, and its rocks are ordinarily but little metamorphosed. They are immediately preceded in age by a series of *micaceous and quartzose slates*, which usually contain some beds of limestone. Both these groups occur only at some distance from the Comstock vein. Of more importance for the latter is a third series, of *hornblendic* (uralitic) *rocks* with interstratified layers of quartzite, gray slate, and crystalline limestone, which is often accompanied by extensive deposits of very pure specular iron. These rocks, form the hills which flank American Flat to the west, as well as those between Silver City and Carson. They are capped by an overflow of *Quartzose porphyry*, an eruptive rock, which, however, is of no importance, except as forming the footwall of the Justis vein.

These rocks form the *ancient series*. They partly preceded, and partly were contemporaneous with the

gradual emergence of the Sierra Nevada and the Great Basin, and the entire chain of the Cordilleras, from the ancient sea, whose traces are left in saline incrustations and salt pools at the bottom of the numerous basins between the Sierra Nevada and the Rocky mountains, which had formerly remained filled with the water of the retiring sea. The Washoe mountains formed undoubtedly an elevated range during the long period which elapsed till the commencement of the formation of the *recent series* of rocks, which bear still closer relation to the Comstock vein than the former. These rocks are eruptive and volcanic, and belong to the latter part of the tertiary and to the post-tertiary periods.

To the first of them in age we apply the recently-introduced term: *Propylite.* In Washoe the names "feldspathic porphyry" and "hornblendic porphyry" are commonly used to designate two prominent varieties of it. They are very appropriate miners' terms; but, scientifically applied, would be capable of very differing interpretation. In other countries the terms "Diorite," "Dioritic porphyry," "greenstone," "porphyritic greenstone," and "trachytic greenstone," have been applied, which confusion of names shows best the indistinctness of the external characters of the rock. Propylite has this remarkable peculiarity, namely: that it resembles many ancient rocks exactly in appearance, and yet is among the most recent in origin. It is prominent among the enclosing rocks of the Comstock

vein and, besides, *encloses several, perhaps most, of the largest and most productive silver veins in the world,* as those in the Karpathian mountains, of Zacatecas and other places in Mexico, and probably several veins in Bolivia. Mineralogically, it consists of a fine-grained paste of ordinarily greenish, but sometimes gray, red, and brown color, with imbedded crystals of feldspar (oligoclase) and columns of dark-green and fibrous, seldom of black, hornblende, which is also the coloring matter of the base. A peculiarity of the rock is its ferruginous character when decomposed. Probably it contains other metals besides iron. Geologically, it is an eruptive rock; but it is accompanied by vast accumulations of breccia, which is sometimes regularly stratified. The flats of Virginia City, Gold Hill, American City, and Silver City, consist of propylite; it lies, in general, east of the mountains consisting of the ancient formations, and contains several mineral veins besides the Comstock lode. Its distribution in other countries of the world is not very general.

Several different kinds of eruptive and volcanic rocks followed the outbreaks of propylite; but only to one of them have we to direct attention in reference to the Comstock vein, as it probably caused its formation, besides taking a prominent part in the structure of the country. It is known in Petrology by the name of Sanidin-trachyte; for convenience sake we simply use the name *Trachyte.* Its essential character is the predominance of a species of feldspar, called glassy

feldspar or sanidin, which, along with hornblende and mica, is imbedded in a base or paste of a peculiarly rough texture, caused by microscopical vesicules which fill the rock. It has a beautiful appearance and presents very different colors. Several superior qualities render it of great use in Washoe as building material; all the masonry of the Gould and Curry Mill is constructed of trachyte; some laminated varieties break easily into regular blocks used for stairs and pillars. Also ordinary varieties yield easily to the blow of the hammer, and break into conchoidal fragments; it forms, therefore, an easy blasting rock—a quality which will come considerably into account for the construction of a deep adit level.

There is no doubt about the eruptive origin of trachyte. It even presents the aspect of volcanic lava, and this term has been applied to it in Washoe. The mode of occurrence shows that it has been ejected through long fissures, in a viscous or liquid state and at a high temperature. In some places the eruptions were subaqueous, as in the vicinity of Dayton. The entire table-land around that place is built up of stratified trachytic tufa. The solid trachyte rises from it in rugged mountains, which form an elevated and very conspicuous range, passing east of the Gould and Curry Mill, across Seven-Mile Cañon, (where, for instance, the Sugar-Loaf Peak consists of it) and bending in a semicircle round to Washoe Lake. Pleasant Valley is entirely surrounded by trachytic hills; and

farther north, this rock covers the country to great extent.

Sanidin-trachyte has never been found to contain silver-bearing veins; and in Washoe none occur in it, and yet it has evidently been mainly instrumental in the formation of the Comstock lode and other veins in that region.

No geological events after that epoch are worth noticing, for our present object. Eruptions of basaltic rocks were considerable in adjoining parts of the Great Basin, but have been of little consequence in Washoe. Volcanic and eruptive activity gradually died away, and we behold now their last stages in the action of thermal springs, such as Steamboat Springs. The surface underwent but slow and gradual denudation; and the events of the volcanic period are recorded so perfectly and distinctly in the nature and association of the rocks, as to aid us greatly in explaining the mode of formation of the Comstock vein.

GENERAL STRUCTURE OF COMSTOCK VEIN.

The Comstock vein runs, nearly in the direction of the magnetic meridian (the variation being fifteen degrees east) along the eastern slope of the Mount Davidson range, which descends at a steep grade until it abuts against the gentle slope of three "Flats," on which, at an altitude of from five thousand eight hundred to six thousand two hundred feet, are situated the

towns of Virginia, Gold Hill, and American City. The outcroppings of the vein extend in a broad belt along the foot of the steep grade and immediately above the three towns. The course of the vein, as far as yet explored, is somewhat dependent on the shape of the slope, as it partakes of all its irregularities, passing the ravines in concave bends and inclosing the foot of the different ridges in convex curves; the greatest convexity is around the broad, uninterrupted foot of Mount Davidson itself. These irregularities are of importance, as they influence the ore-bearing character of the vein.

The length to which the Comstock vein has been traced with certainty, is about nineteen thousand feet, (from Utah mine to Caledonia tunnel, south of Overman mine) while its total extent is, probably, at least twenty-four thousand feet. The most extensive explorations are between the Ophir North mine and the Overman, a distance of about eleven thousand feet; at other parts but little or only superficial work has been done. This applies particularly to the northern and southern ends, as well as to some short portions of the central part. Several mines are being worked to more than five hundred feet in depth, while some of the shafts, as those of the Mexican, Hale and Norcross, Gould and Curry, and other mines, descend to more than seven hundred feet below the outcrops. Altogether, the amount of work done up to this time is sufficient to show clearly the structure of the vein in its upper portion, and to allow well-founded conclusions to be

drawn in regard to those which are below the present works.

Without entering here on the question of the "plurality of veins," or the correctness of the so-called "one ledge theory,"—the discussion of both of which has caused expensive and bitter litigation and retarded the development of Washoe, but at present is decided in the minds of probably everybody—we simply state in the following those facts which may be considered as proved by evidence.

The Comstock vein, at a depth of from four hundred to six hundred feet beneath its lowest outcrops, fills a fissure of from one hundred to one hundred and thirty and even two hundred feet in width, but contracting at places so as to allow both walls to come in close contact. Both of the latter, at that depth, descend easterly at an angle varying from forty-two to sixty degrees. Upwards, from the average depth of five hundred feet, the western wall rises to the surface with the same inclination, which, however, occasionally diminishes at upper levels, to forty and thirty-eight degrees, while the eastern wall soon bends to the vertical and gradually turns to a western dip, which at places is forty-five degrees. Its general position to the depth mentioned, is, therefore, about vertical, with an inflation to the west. The vein, consequently, expands towards the surface, in the shape of a funnel. The increase in volume is especially produced by the intervention, between the vein-matter,

of large fragments of country-rock, broken from the walls, but usually moved only a little way downward, by sliding, from their original place. The bulk and number of these fragments, or "horses," increases towards the surface, where some of them have a length of almost one thousand feet, and a width of fifty to upwards of one hundred feet. Vein-matter, branching off from below, fills the spaces between the fragments, but is generally near the surface far inferior in bulk as compared with the country-rock. The width of the belt in which these branches come to the surface, and there form scattered outcroppings, is generally more than five hundred feet.

On the western side (west of the Virginia and El Dorado croppings) the Comstock vein is accompanied by a number of smaller veins, the outcroppings of which are visible on Cedar Hill, Central Hill, Ophir Hill, and Mount Davidson, and are with some of them of considerable size. They are nearly parallel to the main vein, and dip to the east. Probably they will unite in depth with the Comstock vein, which, by its relation to them, may be considered as the main vein of what German miners call a "Gangzug." The western boundary of this main vein is exceedingly well defined, by a continuous clay selvage lying on the smooth foot-wall and separating the vein-matter very distinctly from the country; but it is different on the eastern side, where the adjoining country-rock, as is often the case with true fissure-veins, is impregnated

with matter similar to that which fills the fissure. It is frequently concentrated in channels running parallel to, or ascending from, the vein, but in fact forming parts of it. The well-defined east wall of its main body has, therefore, often not the same position relatively to the entire vein, and with the growing depth gained by successive explorations, the development of vein-matter east of what was formerly considered the east wall, increases.

Enclosing Rock.—The rocks which accompany the Comstock vein, change in its course. They are different varieties of propylite on the eastern side, throughout its whole extent. In some places the frequent and large crystals of feldspar give it a porphyritic character, which in certain varieties is rendered more striking by green columns of hornblende; at others, the rock has a very fine grain, and the enclosed crystals are of minute size; again, the rock is either compact and homogeneous, or it has a brecciated appearance from the inclosure of numerous angular fragments. Also the color changes, though it is predominantly green, and the different degrees of decomposition create, finally, an endless variety. We will presently have occasion to consider the causes to which it is due.

The western country offers more differences. Along the slope of Mount Davidson and Mount Butler, from the Best and Belcher mine to Gold Hill, it is formed by syenite which, at some places, is separated

from the vein by a fine-grained and crystalline rock of black color, having the nature of aphanite, but altogether obscure as to the mode of its occurrence. It is from three to fifty feet thick, and the elucidation of its real nature may be expected from further developments. As syenite to the west, and propylite to the east, occur just in that portion of the Comstock vein which has been most explored, and where works, more than anywhere else, extend in both directions into the country, it has been generally assumed, in Virginia, that the lode follows the plane of contact between two different kinds of rock, and is therefore a contact deposit. But immediately north of Mount Davidson, where propylite extends high up on the western hills, this rock forms the western country as well as the eastern, as at the California and Ophir mines—though at the latter, metamorphic rocks and syenite are associated with propylite, on the western side. On Cedar Hill, syenite again predominates; but, farther north, propylite forms the country on both sides. South of Gold Hill, the syenite disappears from the western wall, and its place is taken to some extent by propylite, but in greater part, by metamorphic rocks of the third of the before-mentioned classes, principally quartzite and uralitic rocks. They are best exposed in the Caledonia tunnel. Nowhere have syenite and metarmorphic rocks been found occurring on the eastern side.

Outcroppings.—The outcroppings of the Comstock vein do not form a continuous line, but consist rather of small and detached ranges of quartz, ordinarily protruding from the surrounding ground, and sometimes forming bold crests, which, in the aggregate, constitute a broad interrupted belt. The horizontal distance across the vein of the outcrops of the different branches, amounts to upwards of six hundred feet. Those of the western branches, which retain the eastern dip of the western wall of the vein, carry principally crystallized quartz of a very glassy appearance, ordinarily of white or at least light color, and comparatively pure quality. Angular fragments of the country-rock are imbedded in the quartz, and form the centers of its crystallization; they usually occur in large pieces, and not in finely-disseminated particles. Metalliferous minerals are scarce, though nowhere entirely wanting. Nothing indicates underground wealth, nor, indeed, has such been found by subsequent mining. The only exception is Cedar Hill, where native gold was found abundantly in places; but its scarce dispersion never justified great expectations. Of this nature are the Sacramento, Virginia, and El Dorado outcrops, and others on Mount Davidson and Mount Butler. They have in several places a width of one hundred and twenty feet, besides other branches which form part of them.

In the eastern outcrops, particles of the country-rock, together with others of clayey matter and metal-

lic substances, occur, finely-disseminated, through the quartz, causing thereby a marked difference from the character of the western outcrops. A certain porous structure of the quartz, evidently originating from the removal of fine particles of ore, and the brown and red coloring caused by metallic oxyds, indicate the ore-bearing character of large portions in depth; and the dissemination of native gold and silver in small pores and larger cavities, gives evidence of the presence of ores of the precious metals. Also the chloride and simple sulphuret of silver occur in the eastern outcrops. These different characters of the "Pacos" and "Colorados" of the Mexican and the "Iron hat" of the German miner, continue downward to varying depths.

Vein-Matter.—The vein-matter of the Comstock lode is of a highly varied character, if we consider every substance which enters into the composition of the body of the vein, between its two walls, as belonging to it. Its chief component parts are: fragments of country-rock, clay and clayey matter, quartz, and ores.

Fragments of Country-rock. — Near the surface, about five-sixths of the mass of the Comstock vein consists of fragments of country-rock, "horses," as the Cornish miner calls them; they are often of larger size and then terminate below in a sharp edge. Their shape

and size varies somewhat with the different nature of the rock of which they consist. Those of propylite, which along the whole range occur on the eastern side, and only occasionally extend throughout the whole vein where the country is of the same character on both sides, are ordinarily very much elongated in the direction of the vein, frequently to one thousand feet or more, while their breadth is far inferior and their height is intermediate between both. At their ends they thin out gradually. Those of syenite terminate more abruptly and their dimensions are more equal, though they are always largest in the direction of the strike of the vein. From the large "horses" every variety of size occurs down to the smallest fragments. The quartz is often so thickly filled with angular pieces as to have a brecciated appearance. Propylite is more common among them than syenite, and brecciated vein-matter is therefore prevalent in those parts of the lode where propylite encloses the same on both sides, or where, at least, it furnished the larger part of the material for the "horses." It is for this reason abundant in the California, Central, and Ophir mines, and in the southern part of the Gold Hill mines.

Clay and Clayey Matter.—Few large veins are so abundant in these substances as the Comstock vein. Clay forms the western and eastern selvages from north to south in continuous sheets, sometimes of

from ten to twenty feet in thickness. Other sheets of clay divide "horses" from quartz or different bodies of the latter; and where the two walls come in close contact, they have at places a united width of from fifty to sixty feet. This clay is ordinarily tough and putty-like, and contains rounded pebbles of the adjoining rock; only where quartz is on both sides, it partakes of its nature and is more earthy and dry. But, besides, clayey matter occurs in the body of the vein to great extent, and at places takes a prominent part in the filling of the fissure. Most "horses" terminate at their lower end in a clayey substance, and continue downward, as well as in the direction of the vein, as sheets of clay. Outside of the vein, the same matter occurs to great extent in the eastern country, but scarcely, if ever, in the western, thereby giving another evidence of the indistinctness of the eastern boundary of the vein.

Quartz.—The differences mentioned before as prevailing in the quartz of the outcrops continue downward; but are not so conspicuous in depth, on account of the general white color of the quartz. But even there the finely-disseminated particles of the wall-rock are more peculiar to the eastern than to the western portions, and are always abundant where the quartz contains ore. At upper levels, some bodies of quartz are of a reddish color; this is where the "colorados" continue downwards. Frequently, how-

ever, this color is only due to the red clay filling the fissures of the fractured quartz. In this case it is probably produced by the percolation of the vein-matter by water, while in the former it is likely that it is connected with the original formation of the vein, as all the phenomena presented by the "iron hat." The quartz in the Comstock vein is rarely solid, and blasting is applied for its removal in but few instances. Generally, it is fractured, and, at numerous places the effects of dynamical action on it are such as to give it the appearance of crushed sugar. It occurs in this condition almost always when enclosed in clayey matter, and then frequently reminds one of the waving lines of damask. But then, also, large and continuous bodies, consisting entirely of "crushed quartz," as we may call it, are occasionally met with. Such was the case throughout the larger part of the great "bonanza" of the Ophir mine.

Ores.—The principal silver ores of the Comstock lode are: stephanite, vitreous silver ore, native silver, and very rich galena; in small quantities occur: pyrargyrite or ruby silver, hornsilver, and polybasite. Besides these are found: native gold, iron pyrites, copper pyrites, zincblende, carbonate of lead, pyromorphite (both the two last named very scarce).

Other Minerals.—The Comstock vein is remarkably poor in a mineralogical point of view. The ores

are seldom crystallized, and specimens, which at other mines would be considered very common, are admired in Virginia as rareties. In regard to the accidental minerals the same might be said, as they do not occur in either rare or beautiful forms. Quartz is the only gangue. Carbonate of lime very seldom accompanies it, while other carbonates, as those of lead and copper, have only in a few instances been observed. Sulphates are abundant in the waters which issue from the mine, and cover the walls of the old drifts. But the only one forming an essential part of the vein, is gypsum, which occurs in a number of places; it abounds in the lowest works of the Gould and Curry mine, and was formerly found in large crystals in the Fairview. Sulphate of baryta has not yet been observed. Zeolites are limited to the northern portion of the vein, where chabasite and stilbite fill small fissures and cavities in propylitic breccia within the body of the vein.

Distribution of Ores in the Vein—(a) *North of Gold Hill.*—The ore is distributed in a different way in the northern and in the southern part of the Comstock vein. The passage between the two modes of occurrence is gradual. In the northern part the ore is concentrated in elongated lenticular masses, of which the greatest axis is not far from the vertical, but dips to the south and sometimes also to the east. Their width across the vein varies from fifteen to fifty

feet. Sometimes several of them adjoin each other laterally in such way, that the westernmost one extends farther north than the one adjoining to the east, and this, again, farther than its next eastern neighbor. This is most conspicuous in the Gould and Curry and Savage mines, where, at the same time, the western bodies extend, in general, higher up towards the surface. Three or four bodies of ore, arranged in the way described, and either separated by country rock or adjoining each other closely, may be distinguished in these mines. Their total length from the northwestern to the south-eastern and lower end, is about six hundred and fifty feet; their aggregate width about one hundred to one hundred and twenty feet; while their extent downwards is not yet known. They belong to the middle and eastern portion of the vein. The ore has been exceedingly rich in the center of the different bodies, where, at the same time, it was soft and could easily be removed, while the outer parts are hard, and consist of second-class and low-grade ores. Upwards of twenty millions of dollars have been extracted from this immense bonanza. In the Ophir and Mexican mines only one body of similar shape was found. It commenced on the surface, where it was only two feet wide, and descended to the depth of three hundred and thirty feet. It first gradually increased in width, until it reached forty-five to fifty feet, which was the maximum; then, it thinned out again in its downward course, and terminated as narrow as it

commenced. As it was next to the east wall, it dipped with that towards the west, near the surface; then, in its widest portion, straightened out and gradually turned to an eastern dip, with which it terminated. The length of this body was two hundred feet; it appears that about seven millions of dollars have been extracted from it, with the imperfect processes used during the first years of mining at Washoe. This deposit was accompanied to the west, at about forty feet distance, by another body of ore, which, however, had the shape of a narrow sheet, its total width being six to fifteen feet, and its length about three hundred and eighty feet. It was parallel to the western boundary plane of the former body, but extended north and south beyond its limits, though, generally, it did not reach to equal depth; in the Mexican, however, it continued downward about three hundred and fifty feet. The amount extracted was about three and a half millions of dollars. Compared with the first body, it contained a large proportion of lead and copper.

The space between the Ophir and Gould and Curry mines has yielded but very little ore. The Central mine extracted some from the continuation of the deposits worked in the Ophir, and the California found a large body of quartz extending to its lowest level, but the ore was scattered and rarely of rich quality. The next four mines south of it, and the northern half of the Gould and Curry mine, have been unproductive. But the explorations were not

extended more than a few hundred feet beneath the surface.

The southern part of the Savage mine, and the Hale and Norcross, have been almost entirely unproductive, though both of them offer good prospects for finding ore in depth. But with the Chollar-Potosi commences another rich part of the Comstock vein. On the northern line are the so-called Bajazet chimneys, two bodies of ore, separated by about eighteen feet of barren rock, each from twelve to twenty feet wide and about eighty feet long. They have been worked several hundred feet down, and their end seems not yet to have been reached. Their greater axis dips about sixty degrees to the south. With the next deposit to the south, a different shape makes its appearance, which is more perfectly developed in Gold Hill, that of very long and narrow sheets of ore intercalated in the quartz and parallel to the eastern wall, or at least to a distinct clay seam which bounds the main body of quartz to the east. The Potosi deposit is about two hundred feet long, and contained rich ore to the width of from six to twenty-three feet. It commenced near the surface and has been mined without interruption to the depth of four hundred and ninety feet. Its northern and southern boundary lines dip south. A considerable body of poor ore lies adjacent to and parallel with it, and is at present being extracted. Some narrow "chimneys" have been found in lower levels west of this body. After some interrup-

tion the latter continues along the so-called eastern clay for a long way, and has been explored by the Chollar company. It first made its appearance at the depth of about three hundred and eighty feet, and had at one place a width of fifty-five feet; but it soon terminated in depth. The entire length of the eastern body of ore of the Chollar-Potosi mine, excluding the Bajazet chimneys but including some short interruptions, is about seven hundred and fifty feet; and even farther south ore occurs along the eastern clay, but scattered and not worth extracting at the present time. Quartz fills here the entire width of the vein from the western to the eastern wall, and in no part can its unity be more clearly recognized. It continues with a similar character in the Bullion mine, the northern part of which consists entirely of ore-bearing quartz of about one hundred and twenty feet in width. But at the levels worked up to this time it is too poor for extraction, as the ore is not concentrated in distinct bodies.

(b) *At Gold Hill and South of it.*—The occurrence of ore in "chimneys," and of barren portions between them, ceases entirely at the divide between Virginia and Gold Hill. The great wealth of the mines south of it consists in the continuous ore-bearing character of the lode for a length of fifteen hundred and forty feet, from the Alpha mine to the middle part of the Yellow Jacket, and of other extensive portions farther

south. The vein is by no means ore-bearing in its entire width; but the ore is concentrated in continuous sheets, the principal one of which is very near and parallel to the eastern wall, and but little interrupted in its entire length. Its widest places, which are from forty to fifty-five feet, are in the Imperial, Bacon, and Empire mines, and again in the Yellow Jacket. In most places it commenced at from one hundred and fifty to two hundred and fifty feet below the surface; and in many mines it is still worked at their lowest levels. It is wider in the three first-mentioned mines because there united into one mass. South of the Empire it forks into three branches, the two western ones continuing in an irregular way. Besides this very extensive eastern body, there is another one in the Gold Hill mines farther to the west, which extends from the outcroppings down to from one hundred to two hundred and fifty feet in depth, and dips at an angle of fifty to sixty degrees to the west. It was worked out in the early and most flourishing time of Gold Hill, and considerable amounts were extracted, as its width was from twelve to twenty-two feet, and the ore very rich, particularly in gold. It continued in length, without interruption, for about five hundred feet. A similar body was worked out in the Yellow Jacket, the Crown Point, and the Belcher. It was not quite continuous, but at each of the three places was several hundred feet in length. Everywhere it dips to the west at about sixty degrees, and at some depth,

which, as we recede from the northern Gold Hill mines, slightly but constantly increases, flattens out to the west, the bottom being nothing but clay in horizontal layers. Also its southern portion was remarkable for its high yield in gold and for its rich ores in general, but its width was here only from six to twelve feet. The southernmost continuation of this body was found in the Overman mine, where it is likewise rich in gold, but is limited in extent.

The upper portions of the Gold Hill mines are but little explored, and even at lower levels the works were never extended to the western branches of the vein. When the bottom of the first deposit was reached and its wealth found to terminate in clay, the owners of the mines became discouraged; but explorations from that clayey bottom towards the east, brought them to the place where the real wealth of their mines is accumulated and will probably last for a long time to come. The eastern bodies were first found in Gold Hill proper, then in the Yellow Jacket, the Kentucky, and Crown Point, while the Belcher and Overman mines have not yet succeeded in finding them.

Another subject which we have to consider, in connection with the mode of distribution of the ore, is the change in its yield. It is a matter known to every Washoe miner that, in general, it has decreased. The deposits of the Ophir, and Mexican, and of the Gould and Curry, were the richest. The former yielded, at an average, one hundred and seven dollars per

ton; the latter, seventy to eighty dollars, notwithstanding the imperfect processes of extraction which were formerly applied. Ores of six hundred dollars to the ton were then no rarity, and considerable shipments could be made of such as yielded from two thousand to three thousand dollars to the ton. It would now scarcely be possible to collect one ton of such ore, excepting when old works, in the highest levels, are being overhauled. Ores of three hundred to four hundred dollars are now of as rare occurrence as formerly those of fifteen hundred to two thousand dollars. The yield of the middle and low-grade ores has also considerably diminished; and, by far, the majority of the ore, which is being extracted at this day, contains at an average not more than thirty to thirty-two dollars, while the general average of all the ores will not be more than thirty-seven dollars to the ton. This decrease applies for the total amount of ore extracted; but it is equally true for every single mine. The quantity of ore extracted has remained stationary for a long time past, and is now about twelve hundred and fifty tons daily. But the methods of reduction have improved, and their expenses been diminished; therefore, ores of lower grade than formerly can now be worked profitably.

During the early period of the working on the Comstock lode, the proportion of gold and silver changed considerably, the yield in gold decreasing constantly. But as a greater depth is being reached, the proportion of gold is again on the increase.

As some general rules, in regard to the mode of distribution of the ore, may be observed:

1st. The ore is, in the northern part of the vein, concentrated in chimneys, dipping at an angle of sixty to eighty degrees to the south; in the southern part, it forms continuous sheets of great length, but which are comparatively narrow.

2d. These deposits of ore are enclosed in the eastern and sometimes also in the middle portion of the vein; the western branches are barren or poor.

3d. The richest and largest deposits have been found at those places where the outcrops (including those of the western branches) were most prominent, namely: at the Ophir, the Gould and Curry, the Savage, the Chollar, the Gold Hill mines, the Yellow Jacket, the Crown Point, and Belcher.

4th. In the northern part the vein is, at the levels explored up to the present time, invariably poor where it passes a ravine (as in Ophir, Central, Mount Davidson ravines, and the one which divides Mount Davidson from Mount Butler). But in the southern part, the ore continues in the ravines (Kentucky mine and Segregated Belcher).

5th. The richest portions are south of each ravine crossed by the vein.

6th. All the chimneys in the northern part are at those places where the walls from close contact rapidly diverge to the south and cause the vein to expand.

7th. All the principal accumulations of ore are at those places where most room was given in the fissure for the deposition of quartz, and are therefore generally rare where an unusual amount of "horses" obstruct the vein (except North Potosi chimney in Gould and Curry mine).

I have dwelt on the subject of the distribution of the ore in the Comstock vein to some length, because I consider its examination as being of great importance to enable us to draw conclusions in regard to the mode of continuance of the vein in depth.

COMSTOCK VEIN A TRUE FISSURE VEIN.

A true fissure vein may be designated as *a fissure proceeding from indefinite depth and filled mainly from below, by chemical processes, with matter differing in nature from the country-rock.* Great importance appears lately to have been attached to the question whether the Comstock vein is a true fissure vein or not. Though it would be a perfect absurdity to range it among any other class of mineral veins, yet this question will be examined in the following pages, and I will try to show that the Comstock vein possesses, more than almost any other vein, all the peculiar features of a true fissure vein. As such may be considered:

1*st. A true fissure vein extends indiscriminately through different rocks.* It was mentioned in the

foregoing pages that the Comstock lode is but in part of its course enclosed between syenite and propylite on both sides, and, again, at others has metamorphic slate, especially quartzite and hornblendic rocks, on the western, and propylite on the eastern side.

2d. *True fissure veins extend down to indefinite depth.* This fact cannot be practically proved in any other way than by following the vein in its downward course. A few veins have been worked to the depth of a little over 2,000 feet. This is very inconsiderable compared with the depth to which true fissure veins are assumed to extend. There is, in fact, in regard to this question, but little difference whether works on a mineral lode extend to the depth of 500 or to that of 3,000 feet below the surface, as it may in either case terminate at a limited depth with equal likelihood, unless strong and convincing reasons make it evident that the vein, having the character of a true fissure vein, extends downwards indefinitely. Comparison with metalliferous veins of other countries would easily show that it is highly probable that the Comstock vein, which exceeds almost all of them in the magnitude of its proportions, extends to as great a depth as has yet been reached by mining in any country. Farther on, we shall be able to adduce evidence sufficient to demonstrate not only the probability, but almost the certainty of the continuance of this vein in depth, in speaking of the mode of formation of the Comstock vein.

3d. *True fissure veins show evidences of dynamic action*, besides the mere act of the opening of the fissure. Not only has the country-rock on one side generally moved downward on the other, but also within the space formed by the opening of the fissure powerful dynamic action has taken place. Few veins present these phenomena so distinctly as the Comstock vein, the eastern side of which has apparently moved downward on the western. The "horses," besides, and the numerous fragments causing the brecciated structure of parts of the vein-matter, the clay-selvages accompanying it on both sides, the clay-seams and masses of clayey matter in the body of the vein, the waving damask lines of the crushed quartz enclosed in the clayey matter, all these phenomena furnish ample evidence of violent and extensive dynamic action having taken place within the body of the vein. The Comstock vein possesses a certain plasticity shared by few other veins, which allowed that action to manifest itself on a grander scale than it usually does.

4th. *True fissure veins are ordinarily found to be connected with the ejection of some eruptive rock*, and where this is not visible at the surface, disturbances of strata and metamorphic action make its presence underground probable. With the Comstock vein, this accompanying rock, which was instrumental in its formation, is plainly visible. It does not require great sagacity to see at once the intimate connection which exists between the formation of the fissure as well as

its filling, and the outbursts of the before-mentioned trachytic rocks which form a range of hills east of the vein and almost parallel to it, at about two miles distance.

5. *True fissure veins are filled mainly from below, and essentially by chemical action.* This statement, as well as the foregoing, we shall try to prove for the Comstock vein in treating of the mode of its formation.

We shall now turn to the negative proof, that the Comstock vein can only be a true fissure vein because it possesses none of the characteristics of any other class of mineral veins. We may, besides the true fissure veins, distinguish the following classes: gash-veins segregated veins, contact veins, and intrusive veins.

Gash-veins fill crevices limited to the formation in which they occur, that is to say, not passing from one set of beds into another of a different character. The crevices have their origin in shrinkage, from loss of moisture, or diminution of heat; the filling is mainly due to infiltration from above and from the sides, and to precipitation from the water of springs. The magnitude of the fissure of the Comstock vein excludes those modes of origin which created the limited crevices of gash-veins, and must have a grander and more deep-seated cause. The fact that it passes through rocks of very different nature, also removes it far from gash-veins in character. Moreover, it would be impossible to explain, even if

fissures having the nature of gash-veins could attain such magnitude, the mode of filling them with substances such as the Comstock vein contains, either as to quantity of vein-matter, or the quantitative proportion of different metals, or the mode of their combinations. It may also be noticed that gash-veins are of far rarer occurrence than is ordinarily supposed. It appears, that especially all silver lodes, that is, those which contain this metal in sufficient quantity to make it the chief object of mining, are true fissure veins. This character is proved beyond doubt for the veins of the Carpathian mountains, of Freiberg, the Hartz mountains, the provinces of Murcia and Granada in Spain, and it appears to be even true for those of Kongsberg in Norway, which are seldom more than one inch wide, but have been followed with great regularity downward to the depth of 1,800 feet. For the generality of the silver veins of Mexico it is likewise an established fact; and only for those of South America some doubt was entertained, and many of them were supposed to be gash-veins. But this is proved not to be the case as mining works become more extended; on the different lodes of the three greatest mining countries in South America: Pasco in Peru, Potosi in Bolivia, and Chañarcillo in Chili, the character of the silver-bearing lodes as true fissure veins is established beyond doubt. If no other proofs of the continuity of the Comstock vein in depth could be given, it would yet be preposterous to

consider one of the greatest silver veins a gash-vein, since no argentiferous lode has ever yet been proved to be of this character, not even those which are smallest and least developed.

Segregated veins, according to Whitney, do not occupy a previously-existing fissure in the rock, being so enclosed and limited on all sides by it as to show that the metalliferous and mineral substances of which they are made up, could not have been introduced into their present position in any other way than by gradual elimination of their component particles from the surrounding formation. They usually occur in metamorphic rocks, and lie parallel to their cleavage planes. They have no clay-selvages, and contain no "horses," so there could be no appearance of dynamic action within the vein. It is evident that the Comstock vein does not belong to this class.

Metalliferous deposits at the contact of two different formations are ordinarily of irregular shape, but they frequently form *Contact veins* with selvages. The Comstock vein has been considered to be of that character, on account of its following the plane of contact between syenite and propylite. But the proof which we have given in the preceding pages of its passage into different kinds of rock, and its partial enclosure by propylite on both sides, is sufficient to show that the formation of the fissure was only in so far dependent on the contact between two different formations as it followed the same accidentally in part of its

course, probably because the resistance along it was inferior to that offered by the solid masses of rock on either side.

Uniformity of composition from one wall to the other, and equally through the whole extent in length, is one of the characteristic features of all *Intrusive veins*, part of which are ordinarily called *dykes;* these are homogeneous throughout, except that the texture of the crystalline matter may be coarser or finer in places. They have been formed by the forcible injection of liquid matter from below into a previously formed fissure. They never possess clay-selvages. The diversified structure of the Comstock vein through its entire mass, and the varied character of the vein-matter, are sufficient to remove all doubts whether it originated in any such way.

All positive and negative evidence which has been adduced in the foregoing pages, goes to show that the Comstock vein possesses more distinctly all the peculiarities of true fissure veins than most other mineral lodes. In many instances it is not easy to decide on the real character of a lode; but this is not the case with the Comstock vein.

MODE OF FORMATION OF COMSTOCK VEIN.

True fissure veins offer a great variety. Every mineral lode may be considered as an individual, peculiar in its nature and differing from all other

veins. A review of those silver veins which furnish the larger portion of the present production of silver, would show wide discrepancies, as to the nature of the enclosing rock, the length and width of the veins, the character of the gangue and of the ores, the distribution and quantitative proportion of metals, the structure of the vein-matter and its relation to the enclosing rock, and numerous other circumstances, which it would require too much space to explain separately. It may justly be concluded that the same differences exist as to the mode of formation. Infiltration from above, infiltration from the walls, thermal action, and other processes, have separately been advocated as the sole origin of all metalliferous veins. But the combined experience obtained from different countries, renders it evident that all of these processes have been active more or less simultaneously in the filling of every true fissure vein; and that the differences which such veins exhibit, were occasioned by the predominance of one or the other of them, and by the influence of the enclosing rock.

The Comstock vein has neither been filled from above nor from the sides, as none of the surrounding rocks could have yielded the immense quantity of vein-matter and ore; and had it been formed in this way, the mass would have a banded and comby structure, which is by no means observable. The eastern rock may, on account of its extensive decomposition, appear to favor the assumption of lateral

infiltration; but this decomposition was effected by ascending currents which have left distinct traces, and which could not have removed any matter in a lateral way. Thermal springs, which are considered by many authorities as the agent which carried mineral matter from below into fissures and to have formed every true vein, would not explain the formation of the Comstock lode. Silica, in such cases, is accumulated around the mouth of the fissures and, though ordinarily removed by denudation, it could hardly be supposed to be so at the Comstock vein as, since its formation, the surface has undergone but slight changes. But, besides, the decomposition of the eastern country, for miles in extent, cannot be explained by the action of thermal springs.

In order to discover the real agent which carried such immense masses of vein-matter from a deap-seated source into the Comstock fissure, we have simply to trace the origin of the latter, and then to observe what processes follow, at the present time, the formation of fissures of similar origin. If these processes are sufficient to produce such results as we observe in the Comstock vein, then it is highly probable that they were instrumental in its formation; and if we succeed in proving, that they have left their unmistakable traces all over the country, we may consider the explanation, though theoretical, as founded on a solid basis.

Origin of Fissure.—The Comstock fissure is, of course, of more recent origin than the rocks which it traverses; and as propylite is predominant in the latter, the fissure must necessarily have succeeded it in age. The only event after the outbursts of propylite, capable of producing such powerful action, was the eruption of trachyte, which accompanies the vein at a distance of two miles to the east. As there is other evidence of its intimate connection with the Comstock vein, we may take it for granted that it caused the rending of the fissure. The more immediate cause of the latter is, in similar cases, the production of a constantly-increasing tension beneath the solid crust ot the rocks of the surface. As soon as such tension is greater than the resistance offered by the crust, it will cause the rending of the overlying rocks and give vent to the agencies by which it was produced. Sanidin-trachyte is a volcanic rock and, though it did not pour out from the craters of actual volcanoes, yet it must have been attended by the same phenomena which accompany the outbreaks of lava. Among them is the rending of fissures which are occasionally of as great a magnitude as the one under consideration.

Filling of the Fissure.—The process which immediately follows the opening of fissures at or near active volcanoes, is the violent emission of steam. A crevice in this state is called a *solfatara.* It has been proved by Bunsen for the volcanoes of Iceland, by Boussin-

gault for those of the South American Andes, by St. Claire Deville for those of the Canary Islands, and by myself for the tertiary volcanoes of Hungary and Transsylvania, that every solfatara, in the course of time, passes through two stages, in the first of which the steam is accompanied by gaseous combinations of fluorine and chlorine; in the second, by those of sulphur; while a third one is ordinarily marked by the emission of carbonic acid and combinations of hydrogen and carbon, at which time the term solfatara is no longer applicable. We have in the elements evolved during the first two periods all the conditions required for filling the Comstock fissure with such substances as those of which the vein is composed. Steam, ascending with vapors of fluosilicic acid created in its upper parts (by the diminution of pressure and temperature, according to well-known chemical agencies) silica and silicofluohydric acid, the former in solid form, the latter as a volatile gas which acts most powerfully in decomposing the rocks it meets on its course. The chloride of silicon in combination with steam forms silica and chlorohydric acid. Fluorine and chlorine are the most powerful volatilizers known, and form volatile combinations with almost every substance. Besides silicon, the metals have a great affinity with them. All those which occur in the Comstock vein, could ascend in a gaseous state in combination with one or the other of them. They must then be precipitated in the upper parts as metallic oxydes or

chlorides, and in the native state. Thus the fissure was gradually filled from its upper portion downwards with all the elements which we find chemically deposited in it. A fissure is ordinarily not stationary after its first opening; but by subsequent action may from time to time widen and frequently contract again. New channels would thus be opened where the old ones were obstructed. If such widening, or opening of an empty space within the matter filling the old fissure, was followed by emanations rich in metallic vapors, then the conditions would be given for the formation of a body of ore of the shape of the newly-opened chasm, which corresponds precisely to most of the bodies of ore in the Comstock lode. Contemporaneously with the filling of the fissure, the adjoining rock would be acted upon by the ascending acid vapors, and its nature by them entirely changed. Cracks would form in it, and be filled with substances similar to those of the vein itself. As the Comstock vein has an eastern dip and the action of forces manifests itself towards the surface, only the rock on the hanging wall, or the eastern country, would be influenced in this way. Crevices branching off from the main fissure would probably penetrate into the hanging wall, and it may reasonably be expected that deeper working will disclose such branches filled with vein-matter, and probably of ore-bearing character, east of the main body of the vein.

Transformation of Vein-Matter.—A transforming action must necessarily take place from the very commencement of the decomposition of matter in the fissure. Sulphurous acid and sulphuretted hydrogen which were among the escaping gases in the first period, together with combinations of fluorine and chlorine, gradually became predominant, marking the second period of solfataric action. But little more matter could be introduced into the fissure, as the combinations of sulphur with mineral substances are not volatile. Chemical transformation was now the principal action within the vein. Silica is deposited from its combinations with fluorine and chlorine in a gelatinous state, very different in its physical characters from those of the crystalline quartz which fills the vein. It must undergo a solution in water with which, in the form of steam, it was impregnated, in order to assume this character. Metallic oxydes and chlorides were converted into sulphurets, and the presence of antimony caused the formation of sulph-antimoniurets, the principal one of which is stephanite. By such processes, the entire vein-matter was gradually converted from its former condition into that which it presents at this day.

Thus, following simply the mechanical and chemical actions observed in active solfataras, and basing our conclusions on experiments made in the chemical laboratory on the processes of precipitation and transformation which must be effected by them, we are led to

precisely the same results which we actually observe in the Comstock vein. The question may still be put as to what was the *origin of the vein-matter*, which in the deep-seated volcanic laboratory was prepared for ascending into the Comstock fissure. As to fluorine and chlorine, they take part in the composition of rocks, but their principal source was doubtless the water which penetrated through the rocks to the region of volcanic activity, and which in the case of active solfataras can alone explain the continuous emanation of volumes of steam. Though the sea, at the time of the formation of the Comstock vein, was far distant, yet the waters of the adjoining basins were, as they are to-day, highly charged with the same salts as are dissolved in sea-water, among them chlorides and fluorides. Fluorine and chlorine, therefore, had the same origin as they are supposed to have in active solfataras. As to the source of the mineral substances, we have to look for the action of those elements on the surrounding rocks. Silica was offered in unlimited quantity, particularly in the trachytic rocks. Every silicate is easily decomposed by fluorine, fluosilicic acid escaping in a gaseous state while some solid residuum remains. For the metals we have to account in the same way, considering the vast quantities of rock which in the depths of the solfataras could be acted upon by the acids. Silver appears, from recent researches, to form, in very small quantity, a constituent part of every rock, and gold probably enters in still

more minute quantity into their composition, while other metals are present in larger proportion, and iron especially forms a considerable percentage in the composition of all rocks. But even those which are present in so small a proportion as almost to escape detection by chemical analysis, may be concentrated, if acted upon by such elements as have most affinity to them, and then carried by them into channels where, when exposed to other influences, they are deposited. It is a fact worthy of notice that there is scarcely a single chemical agent, excepting fluorine and chlorine, which would not carry metallic substances into fissures in exactly or nearly the reverse quantitative proportion from that in which they occur in silver veins. Iron and manganese are not only more abundant in rocks but also much easier attacked and carried away by acids, than silver and gold. The proportion of these to the former ought, therefore, to be still smaller in mineral veins than it is in rocks, and lead and copper ought to be more subordinate, if their removal from their primitive place had been effected by other agents than fluorine and chlorine. Only these two will first combine with those metals which are most scarce in rocks and relatively most abundant in silver veins; and they are probably the only elements which have originally collected them together into larger deposits, though these may subsequently have undergone considerable changes, and water may have played altogether the most prominent part in bringing them into their present shape.

Dynamical Action in the Vein.—The rending of the fissure was the first dynamical action in the history of the Comstock vein. It continued, as mentioned before, in repeated rewidening and partial reclosing. Another dynamical process was the separation of fragments from the hanging wall of the fissure. Small fragments fell into it during the formation of the vein-matter and caused its brecciated structure, while larger ones were separated by the formation of fractures and slid down until they met resistance. Every fissure of active solfataras is closed on the surface by similar fragments broken off from the sides of the fissure, and one may walk on solid ground over the chasm from which steam issues hissing and roaring, escaping from between the rocks and feeding boiling cauldrons. There is no difference between these obstructions and those in the upper part of the Comstock fissure. Other dynamical changes which are still going on constantly, are manifested by the clay-selvages along the walls and the clay-seams in the body of the vein. They indicate a sliding motion of the vein-matter on the walls, and of different portions of the former on each other. Few veins present such plasticity of the vein-matter as the Comstock lode possesses, a circumstance which on one side facilitates mining extraordinarily, on account of the loose nature of the quartz, while on the other part it is the most serious nuisance in mining, as it causes the rapid breaking and caving of old works. Drifts in clayey matter cannot be kept

open by the strongest timbers, those of a foot square in thickness being frequently broken within a few days. The constant movement in the vein may also be witnessed where clay-seams are cut by drifts; after some time the rock on one side is lowered considerably. Mining works probably promote this slow but incessant motion in the body of the vein, since they open outlets for the water, which can percolate the vein-matter freely and diminish its substance by its dissolving power.

Additional Proof of former existence of Solfataric Action.—Though it seems that the Comstock fissure was the principal theater for the emission of steam and all those phenomena which may be comprised by the name of solfataric action, yet the latter left its traces over a wide extent of the adjacent country. The entire belt of rounded hills extending east of the vein for two miles, to the foot of the trachytic range, shows its effects very conspicuously. It consists of propylite; which, however, can scarcely be recognized on account of the complete decomposition it has undergone and which has transformed it into a clayey rock of red and yellow color, but still showing distinctly the enclosed crystals of feldspar and hornblende. It is traversed by numerous crevices from which the decomposition originated, and shows everywhere evidences of vertically-ascending currents which caused it. Whoever has seen active solfataras,

will be struck by the resemblance of the chemical action on the surrounding rocks to that displayed in the region east of the Comstock lode. Near some of the crevices the decomposed rock is strongly impregnated with silica, producing the rangès of red-colored bluffs which accompany the Comstock vein to the east, and which have been partly located as outcroppings of veins, while at about two miles distance real metalliferous veins occur, promising in their outcrops, but not yet explored. Besidès this belt, the former action of solfataras is plainly visible in many parts of the country. The formation of the Comstock vein is but one of its manifestations.

CONTINUITY OF THE COMSTOCK VEIN IN DEPTH.

The problem which above all others occupies at present the minds of miners, stockholders, and speculators in Washoe, is, whether the Comstock lode will continue in depth, and, if it does, whether it will be productive. And these questions are indeed of the highest importance for the future of the country, and ought so much more to be considered with care, as on their solution depend the means which will have to be applied for securing future prosperity and profits.

It was proved in the foregoing pages that the Comstock lode presents in all respects the character of a true fissure vein, and these in such perfect degree as but few veins of this class exhibit. It was furthermore

proved that the mode of its formation can only be explained in one way, namely, by solfataric action connected with the outbursts of trachyte. No theory but this is able to explain the origin of the vast quantities of vein-matter, the profuse diffusion of ore through it, the abnormal quantitative proportion of the metals in the ore, the thorough decomposition of the eastern country for two miles in width, the mode of distribution of the ore in the vein, and the formation of the "horses" which obstruct it in many parts. As the creative forces acted from below, they must have found an open way for the communication of the laboratory below with the place of deposition in the upper portion of the vein. No sound mind can therefore doubt the continuance of the fissure, and therefore of the vein, in depth.

MODE OF CONTINUANCE IN DEPTH.

It is much easier to come to definite conclusions in regard to the question, whether the Comstock lode continues at all in depth, than to state the most probable mode of its continuance. Our deductions as to this subject cannot but be hypothetical, however numerous and well founded the facts and laws may be on which they are based. We may consider the question from different points of view, partly in reference to the structure in general, and partly to the ore-bearing character.

Inclination.—It appears that the real inclination of the Comstock vein coincides with that of the western wall, which is remarkably constant for a distance of nineteen thousand feet on the course of the vein, wherever it has been explored, and for about one thousand feet in vertical extent, from its highest outcrops to the deepest mining works. The angle at which it dips to the east, varies from thirty-eight to sixty degrees, the lower figures being the usual ones near the surface, the higher ones at a moderate depth, while in the lower works the inclination is again forty-five degrees. There is but one reason in favor of the assumption that the lode may straighten out to an almost vertical position. This is the occurrence of "horses," identical with the rocks forming the western country, and the vertical position of the plane of division between these horses and those derived from the eastern country, wherever such difference exists between both sides of the fissure. The assumption that the fissure originally followed this vertical dividing plane would well account for all the phenomena presented by the "horses." But this argument is not strong enough to militate against the regularity of the inclination of the western wall, moreover as the eastern wall was by the mining works proved to make the previously-mentioned bend, and to assume finally, in depth, an inclination parallel to the western wall. There is another argument corroborating the theory of the permanency of the present

dip of the vein of about forty-five degrees to the east, which, from a geological point of view, is more conclusive. As mentioned before, the propylitic rocks for two miles east of the vein have undergone a decomposition which, from its nature, must be ascribed to the former action of solfataras. There can be no doubt, that the currents of steam and vapors, which left their traces particularly on the sides of numerous vertical fissures, emanated from one common source. Since the concentration of solfataric action must have been in the Comstock fissure, where its results are most evident, it appears that this has been the immediate source, and through its inclined hanging wall branched off all those ramifications which spread the decomposing agents through the overhanging rock; this at least is manifestly the case in the lower works, where crevices filled with quartz and clayey matter ascend vertically through the hanging wall, but frequently do not rise to the surface.

Width of Vein.—The indistinct character of the eastern boundary of the Comstock vein often renders the determination of its width difficult. Near the surface it is ordinarily five hundred to six hundred feet, and on American Flat exceeds these figures. With increasing distance from the surface the vein gradually contracts, to that certain depth where the eastern wall begins to descend parallel to the western one; from thence downwards it begins to be more

constant. The real width of the vein cannot therefore be determined before this depth is reached. In general, the parallelism of the walls commences in the northern mines at a higher level than in the southern ones. Five hundred feet may be considered as the average depth at which it is first well marked; but on American Flat it appears to be several hundred feet more. As far as the vein at this depth has been explored from wall to wall, it forms a channel of great regularity and about one hundred to one hundred and twenty feet in width (at right angles to the inclination), though at some places it expands beyond this figure, and at others contracts. South of the Chollar-Potosi mine, the vein is nowhere contracted in width; but north of it, the walls frequently come together. Such places must necessarily occur in an inclined vein of some magnitude, since the hanging wall, during the long periods of the filling of the fissure, required some support. The walls of every true fissure vein are uneven planes. The downward movement of one side of the fissure on the other, at the time of the formation of the vein, caused protuberances of one wall to meet such of the other and concave places to come opposite each other. This is the reason why every large fissure vein is liable to repeated expansions and contractions, though the former prevail largely over the latter. It is to be expected that the Comstock lode will exhibit the same features in its downward course to indefinite depth, as it also has done heretofore,

though its general width will probably remain nearly equal to that which it possesses in the lowest works.

"*Horses.*"—The formation of large "horses" is, from the nature of their origin, more peculiar to upper than to lower levels, since their breaking down from the hanging wall will in every fissure be most apt to take place where the latter is of comparatively inferior thickness, than where it is hundreds or thousands of feet wide. But small fragments may separate from it at any depth, and their quantity will chiefly depend on the nature of the rock and the power of the decomposing agents. It was mentioned before, that the action of the latter was exceedingly violent in the Comstock fissure, fluorine, chlórine, and steam being the principal elements by which it was effected. It is therefore highly probable that the bulk of small fragments will be very considerable at lower depths, and that this will cause the appearance of brecciated vein-matter to great extent, besides forming larger accumulations of barren nature, which will principally be above the places of contraction. This may already be observed in the Ophir mine, in the deepest works at the present time.

Enclosing Rock.—It is not likely that the country-rock adjoining the vein on either side will, in depth, undergo any changes, other than such as may be occasioned by different degrees of decomposition or by an

increase of some of them in extent. The structure of the country indicates that the meridional Mount Davidson range existed at the time when the eruptions of propylite formed an addition to the mountain mass on its eastern side, and that the steep slope of the former continues below the rounded hills of the latter. Probably the fissure followed the plane of division of the ancient Mount Davidson rocks with the more recent masses of propylite, as offering less resistance to the tension below than the rending of the solid mass of one kind of rocks would have done. Only where the old slope deviates from a straight line, the tertiary rocks appear to have filled the depressions, and the fissure to have intersected them. Yet the ravines in the old mountains, which formerly were the same as at present and descend below the propylitic covering, have had some influence, since the vein is known to make concave bends through them. This influence will, therefore, most likely be perceptible to great depth, though it may not always be as unfavorable for the ore-bearing quality of the vein as it has been in the upper levels. If any change as to the enclosing rocks should occur in depth, it is probable that propylite will disappear on the western side and syenite predominate there more and more.

Selvages.—All the evidences in the upper levels justify the expectation that the foot wall will continue with its smooth and regular clay-selvage, while the

irregularity and indistinctness of the eastern side will not diminish, but rather increase as its true character as hanging wall will become more conspicuous. The vertical sheets of clay which have from time to time been cut in the adits east of the vein, rise undoubtedly from the hanging wall. Every one of them, when struck at a lower level, will in its course be considered as east-wall, until another one farther to the east will be found. This periodical change of opinion is already now observable in the deeper mines. Clay-seams within the body of the vein will probably diminish with the increase of unity in inclination. Those which are at present observable at upper levels, are particularly occasioned by the vertical position of the vein-matter, which of course facilitates sliding motions. Larger accumulations of clay will especially continue near the old ravines.

Ore-bearing Character and Distribution of Ore.— Some unfavorable developments made recently on the Comstock vein, have induced even those who believe in its continuity, to have some doubt in regard to its carrying any ore in depth. The question is of great importance, and one in regard to which one may easily arrive at too sanguine views if mines are "in bonanza," and just as easily at too unfavorable results when they are "in borasca." A short review of some facts observed in other silver mines may assist us in drawing conclusions for the Comstock vein.

In no branch of mining are the vicissitudes of this industry so conspicuous as in silver mining. Princely fortunes have been made by it in the shortest time, and equal amounts spent in vain in search of fortunes. The history of the Mexican mines, as chronicled by Humboldt and Ward, furnishes remarkable illustrations; but they would possess a still higher degree of interest if an equally able historian could be found in modern times, who might add those developments which have taken place during the present century. We are told of mines which, after having yielded immense wealth, were abandoned because no more profits could be obtained, and then, after a long lapse of time, were reopened by enterprising individuals, and anew poured out treasures from below where they had been worked before, then were left again, and successfully reopened a third time. The causes of abandonment were either the deterioration of the ore, or the impossibility of making the returns exceed the expenses of keeping the water down, or lawsuits, or, finally, political circumstances. The success of reopening was, in the two first cases either due to the improvement of the ore at some lower level, or to the introduction of cheaper modes of drainage, partly by improved machinery and partly by adit-levels.

The Valenciana mine on the Veta Madre of Guanajuato, was opened in 1760 on a part of the vein on which some work had been done in the sixteenth century, and which afterwards had been neglected as un-

promising for almost two centuries. In 1768 a rich "bonanza" was struck at a depth of two hundred and forty feet, from which $1,500,000 were extracted annually. Still from 1788 to 1810 the yearly produce averaged $1,383,195. A town of seven thousand inhabitants was built near the mine, and thirty-one hundred people were occupied by the latter. A large octagonal shaft was sunk to upwards of two thousand feet, and the mine explored by it in lower parts. But the rich ore extended only to the depth of twelve hundred feet, below which it was then too poor for extracting. In 1810 the mine filled with water. Fifteen years later the Anglo-Mexican Company, with a considerable outlay of money, freed the mine of water, but the ores gave no profit, on account of the expenses of keeping the water down. It is now owned by the United Mexican Company, and for a number of years has yielded immensely by the large amounts of low grade ores which fill the vein.

The Veta Grande, at Zacatecas, which from 1548 to 1832 yielded about $666,000,000, occurs in propylite, as does the Comstock lode, and has a similar structure, the vein branching out towards the surface and descending at an angle of about forty-five degrees. Its width is inferior to the Comstock vein, being generally not more than from one to thirty-three feet, and only at one place increasing to eighty feet. It has clay-selvages and encloses large fragments of country-rock. The ore in the upper levels was concentrated

in chimneys and rich, but with increasing depth it became poorer, though at the same time it was distributed through a much larger extent of the vein. The ore for some time could not be worked with profit, but at present the production of Zacatecas has again reached a very high figure.

In these two instances the ores are poorer in the lower portions of the lode, but more equally distributed and it is the immense quantity of low-grade ores which causes its great productiveness. It is noteworthy that the character of the ores changes in no other respect. They remain true silver ores through all levels. Many other mines offer the same conditions, particularly those in the central part of Mexico. It is different in the northern provinces. The silver mines there are famous for the large amounts of native silver which they produced near the surface, and the quantity of rich ores which were raised from them. They too have poorer ores in depth, but this poverty is due to the increasing predominance of lead over the silver in the veins. The same is true of the silver mines in the Carpathian mountains, all of which are in propylite and resemble the Comstock vein in many respects. The vein of the Grossgrube in Felsobanya is almost its counterpart. This mine as well as those of Schemnitz are said to have yielded immensely in former times, though worked with imperfect processes. Extensive chimneys of ore have been entirely removed by the Romans. In depth the ore is exceedingly poor,

so as to yield but a small profit with the economical mode of working proper to European countries. But this deterioration is chiefly due to the prevalence of the ores of lead and copper in lower levels, true silver ores being of rare occurrence. At the same time the ores become more equally distributed through the entire vein-matter, though they still form in it small seams and bunches.

Other mines retain an equal yield of silver at every depth. Those at Freiberg, though having their bonanzas at different levels, have on the whole rather improved with an increase in depth. Those of Kongsberg, in Norway, had their temporary bonanzas as far down as eighteen hundred feet, the lowest level reached, and have in later times yielded more profits than formerly. Those of Catorce and several other places in Mexico, show likewise no decrease in yield, and have excellent ores at eighteen hundred and two thousand feet in depth. Many other mines of the same nature could be mentioned.

It would occupy too much of our space to enter more fully into the details of other argentiferous veins. If we proceed to compare the Comstock vein with those best explored, it is evident, that it differs in nature from a certain class of narrow veins, which, as those of Freiberg, Kongsberg, Chañarcillo in Chile, Pasco in Peru, Catorce in Mexico, and Austin in Nevada, fill a number of small fissures, which are either parallel or intersect each other, and which exhibit in

depth nearly the same character and richness as near the surface. It presents, on the contrary, all the characters of a second class of silver-veins which are prominent on account of their magnitude and unity, and exhibit wherever they occur, one great mother-vein or "veta madre," surrounded in most instances by some smaller veins of little or no importance. To this class belong the veins of Schemnitz and Felsobanya in Hungary, the Veta Madre of Guanajuato, the Veta Grande of Zacatecas; while the veins of Potosi in Peru and the Biscayna of Real del Monte in Mexico have to be referred more to this than to the former class. Notwithstanding their small number, these great mother-veins furnish by far the greater portion of the silver produced throughout the world. They resemble each other in many points. All of them fill fissures of extraordinary width and length, and appear to be of very recent origin, and also to be intimately related to volcanic rocks, by which they are accompanied. Although the laws which govern the distribution of the ore differ more or less for each vein, yet all of them have been found to be highly metalliferous to whatever depth explored; and it appears that a nearly equal quantity of silver is with most of them contained in each level (the vein of Guanajuato being an exception to this rule). It may be inferred that this will continue to be the case to an indefinite depth. There is, however, a marked difference in the concentration of silver, ores of extreme richness being usually accu-

mulated in limited bodies in the upper levels, while in depth similar bodies recur, greater in extent, but consisting of lower-grade ores. This is one of the principal reasons why, on all the veins mentioned, mining in upper levels has been so highly remunerative compared with the profits derived from deep working. Each ton of ore costs there but little to extract, and yields a large amount of metal, while raising the same weight from greater depth is more expensive, and at the same time a smaller amount of bullion is realized. The history of the Mexican mines is the best illustration of these relations. In former centuries Counts and Marquises have been made by the King of Spain whenever fortune enabled a single individual to accumulate enormous wealth in a few years. Mining, then, was confined to rich ores within a few hundred feet from the surface. In the present century, since greater depths have been reached, the Spanish Crown, if it had still the scepter of Mexico, would scarcely have found an opportunity of bestowing equal honors on fortunate mining adventurers, notwithstanding the unabated enterprising spirit of the population, and the increased facilities of raising the treasures. And yet, the production of the Mexican mines has anything but decreased. It appears, on the contrary, that it has never been as high as at the present time. Humboldt states that vastly the majority of the annual production of Mexico has through all times been derived from the mother-veins alluded to above; and still at this day,

they furnish at least three-fourths of it, though each of them has repeatedly been abandoned as unprofitable. They would be inexhaustible sources of wealth, if the increase of expenses attending the growing depth did not put a limit to all profitable mining.

The equality of produce of the Mexican mines is probably partly due to the prevalence of true silver-ores through all levels. The Hungarian mines offer less favorable conditions, as the ores, on account of the previously-mentioned increase of lead and copper in depth, undergo a real deterioration. Yet they have evidently had at upper levels their concentrated bodies of rich ore. Such have been extracted at Schemnitz within the time of historical record, while their former existence at Felsobanya may be inferred from the shape and character of the old Roman works near the outcroppings.

Let us now return to the Comstock vein, the "Veta Madre" of Washoe, and examine what conclusions as to its future we are justified in drawing from the present condition of the explorations. In the first place, we have to mention the fact that the ores through all the levels explored, retain the character of true silver-ores which they had near the surface. The amount of lead, copper, iron, and zinc has never been large in the Comstock ores, and these metals preserve now, at the lowest levels, nearly the same relative proportion as formerly. Their increase, especially of lead, would be the most unfavorable indication for the future of the

Comstock lode, as, besides the growing difficulty of metallurgical treatment, the conclusion would be justified, that lead ores would more and more replace those of silver, and the limits of profitable productiveness would soon be reached. But, as it is, no deterioration is to be expected, even if an impoverishment takes place. It thus approaches in its ore-bearing character the great mother-veins of Mexico, and is different from those of Hungary.

But even the reasons for an impoverishment are by no means so evident as might appear at first sight. There have been, it is true, bonanzas near the surface, which surpassed in richness all those worked upon in later times. As such may be mentioned the bonanzas of the Ophir, the Gould and Curry, and the western body of ore in Gold Hill. Their richness and the facilities of their extraction co-operated in making the latter exceedingly profitable. Yet the production of the Comstock vein did, at the time when it was solely derived from these surface-bonanzas, not reach the figure it attained after the exhaustion of their principal portion. One of the reasons is, that then the ore was concentrated within narrow limits, while, as a greater depth was attained, the distribution of the ores was much more general, though their standard was lower. New bodies of ore had been discovered, commencing at a depth of from one hundred and fifty to three hundred feet below the surface, such as the continuous sheets of ore in the eastern part of the lode in

the Gold Hill mines and the Yellow Jacket, and the similarly-constituted one in the Chollar-Potosi. None of them contains, excepting a few narrow streaks or bunches, ores of equal richness with those of which the surface-bonanzas were composed. But their extent so far exceeds that of the latter, as to make up, by the increased amount of daily extraction, for the inferior yield. The profits of working are, of course, greatly diminished.

These bodies of ore have continued to the deepest levels reached in the Comstock mines, varying in width and extent, and also in their yield. The latter did not increase, but in some instances, as in the southern part of Gold Hill, decreased with the growing width of the deposit, while in others no material change is perceptible. Few new bodies of ore made their appearance below the level of three hundred feet. Foremost in importance among them are two bodies discovered at seven hundred feet below the surface by the Hale and Norcross works, one of which is on ground supposed heretofore to be unproductive.

Considering these facts exhibited by the Comstock vein itself, and comparing with them what is known about similar argentiferous veins, we believe to be justified in drawing the following conclusions:

1st. That the continuity of the ore-bearing character of the Comstock lode in depth must, notwithstanding local interruptions, be assumed as a fact of equal certainty with the continuity of the vein itself.

2d. That it may positively be assumed that the ores in the Comstock lode will retain their character of true silver ores to indefinite depth.

3d. That it is highly probable that extensive bodies of ore equal in richness to the surface-bonanzas, will never recur in depth.

4th. That an increase in size of the bodies of ore in depth is more probable than a decrease, and that they are more likely to increase than to remain of the same size as heretofore.

5th. That a considerable portion of the ore will, as to its yield, not materially differ at any depth from what it is at the present lower levels; while, besides, there will be an increasing bulk of low grade ores. We are led to this supposition by the similarity in character of all the deposits outside of the rich surface-bonanzas, and the homogeneous nature which almost every one of them exhibits throughout its entire extent.

6th. That the ore will shift at different levels from certain portions of the lode to others, as it has done up to the present time. More equality in its distribution may, however, be expected below the junction of the branches radiating towards the surface, when the vein will probably fill a more uniform and more regular channel. Some mines which have been heretofore almost unproductive, as the Central, California, Bullion, and others, have therefore good chances of becoming metalliferous in depth. But throughout the extent of the vein it is most likely that the portion which lies

next to the foot wall will continue unproductive, as it did from the surface down to the lowest works, while the entire portion between it and the hanging wall must be considered as the probable future source of ore. As remarked in the foregoing pages, it is also probable that repeatedly, in following the lode downward, branches will be found rising from its main body vertically into the hanging wall, and consisting of clay of quartz. Many of them will probably be ore-bearing. Such bodies of ore should be sought for, at all the mines, in what is generally supposed to be the eastern country. Experience in upper levels would lead to the supposition that such eastern bodies might carry richer ores than the average of the main portion of the vein.

7th. That the intervention of a barren zone, as is reported by good authorities to occur at the Veta Madre of Guanajuato, at the depth of twelve hundred feet, is not at all likely to be met with in the case of the Comstock lode. The argument which we have to adduce for this conclusion, has some weight from a geological point of view. It is a well-known fact that the enclosing rocks have usually great influence on the quantity and quality of the ores of certain metals in mineral veins, and that a rich lode passing into a different formation frequently becomes barren or poor. At the Veta Madre of Guanajuato, a sudden decrease in the yield of the ore, at the depth of twelve hundred feet, attends the passage of the lode into a different formation, which from thence continues to the lowest

depth attained. No such change can ever be anticipated for the Comstock lode, since the structure of the country seems to indicate the continuity of the enclosing rocks to an indefinite depth.

In winding up these considerations, we come to the positive conclusion, that the amount of nearly fifty million dollars which have been extracted from the Comstock lode, is but a small proportion of the amount of silver awaiting future extraction, in the virgin portions of the vein, from the lowest levels explored down to indefinite depth; but that, from analogy with other argentiferous veins, as well as from facts observed on the Comstock lode, the diffusion of the silver through extensive deposits of middle and low grade ores is far more probable than its accumulation in bodies of rich ore.

MEANS OF SECURING FUTURE PRODUCTIVENESS.

The main object for those engaged in mining on the Comstock lode should be, to derive the highest possible profits from the exploration of the mines, that is, to devise means for reducing the expenses and improving the methods of reduction. In both these respects improvements have been made heretofore at equal rate with the decrease in the yield of the ore, and profits are now earned from ores which are much poorer than any worked in former days. Yet, by the constantly-increasing expenses of pumping, hoisting,

and keeping the mines in working order, these profits will soon disappear and losses be incurred if no further reduction of expenses takes place. In speculating as to the means required for attaining this end, we have to start from as unfavorable a basis as possible and to employ such as will be applicable even in the possible case of an impoverishment of the ore in depth.

The Comstock mines have this great advantage, that sinking and driving are relatively cheap, owing to the soft nature of the quartz and country-rock. This character will probably not change at lower levels. The best system of mining will therefore be that which makes the best use of this advantage and, at the same time, meets most perfectly and with the least expense the disadvantages resulting from the same quality of the rock. Such a system, which is very different from that formerly in use, is being more and more adopted. The former plan of removing first all the ore in sight, and of commencing exploring work in other parts of the mine only after the complete exhaustion of the former, when the reluctant stockholders are forced to pay for the doubtful success of the work, is not yet abolished; but in some mines is giving way to a more sensible system of exploration. Even if stock-speculation, the greatest enemy of legitimate mining, should hereafter still exert its evil influence on the management of the Comstock mines, yet those other improvements will not fail to act in a beneficial way. So, too, the increasing knowledge of the nature of the Constock vein has

led to an improved system of working. The soft nature of the eastern country compared with that of the hard western rocks, has taught that shafts can only be sunk profitably in the former, and never ought to be allowed to penetrate into the latter. The dip of forty-five degrees to the east makes it a matter of course, that a shaft near the outcroppings will reach sooner the hard foot-wall than one which is constructed farther east. Much money would have been saved if this experience could have directed former operations. Henceforward the working of the mines will be in great degree governed by this idea. The gentle slope to the east, on the surface, of the eastern country facilitates greatly this method of exploration.

Yet all these improvements cannot prevent the profits derived from ores of the present average yield becoming, in course of time, gradually less and at last insufficient to cover the increasing expenses. Shafts must be sunk to greater depths; and the power required for hoisting the ore increases in a rapid ratio. It will be more and more difficult to secure thorough ventilation, and to get rid of the heat and moisture of the air in depth. But more than all this, the water in the mines will be a growing impediment. The power of pumping-machinery is being increased constantly, and the amounts paid for keeping the mines dry have already attained a high figure. At the same time other heavy expenses remain stationary, such as hauling the ores to the reduction works. The cost of reduction on Carson

River, by water power, is not more than five dollars per ton; but is increased to eleven dollars by the cost of hauling the ores from the mines. The mills in the vicinity of the mines are worked by steam-power, and, though hauling to them costs only one dollar to one dollar and fifty cents a ton, yet the aggregate expense is the same as in the former case. The total costs per ton at the mine, if it is very productive, are not less than seven dollars per ton, and as in most cases a considerable profit has to be paid to the owners of reduction works, the lowest limit of profitable working is a yield of twenty-five dollars per ton, with the application of an imperfect method of reduction, and no reasonable profits can be expected from ores which yield less than thirty dollars per ton.

If some means could be devised to lower the expenses of freight to Carson River, where, besides the considerable water-power, steam-power is much cheaper than near Virginia and Gold Hill, and if at the same time the expenses of working the mines could be reduced, the extraction of such ores as are far beneath the present average would then become profitable, and the gains from the latter would greatly increase.

The only possible way of attaining these results is the construction of a deep adit-level or "drain tunnel," as it is called by the Washoe miners. There is probably no silver mine in the world which offers so great facilities and inducements for the performance of such

a work. It is proved that an adit-level of not more than twenty thousand feet in length would strike the Comstock vein about one thousand nine hundred feet vertically below its outcroppings. The construction of the work would be comparatively easy, as the rock to be perforated is far superior to the average of rocks through which adit-levels have been constructed in other countries, in respect to the ease with which they can be excavated. The importance of "drain tunnels" for mines in general has lately been demonstrated repeatedly and illustrated by numerous examples from other countries, in reference to the execution of the work of this kind contemplated for the Comstock vein. I will therefore not dwell here on this subject, but will simply state the various reasons why it appears to me to be the only way of securing the future profitable productiveness of the Comstock mines, and will try to show what additional benefits may be derived from the speedy execution of this work.

1st. The greatest benefit would be, the drainage of the mines, which, by branches north and south, could be effected throughout the whole length of the vein. The amount which is expended for it at the present time will, with the further application of pumps, increase constantly, and so absorb alone all the profits. Adits at upper levels drain usually but a small portion of the vein, as intervening clay-seams retain the water in reservoirs, which have to be tapped in order to be

drained. This inconvenience will doubtless cease with the turn of the vein to its regular dip and course, as the clay-seams within the body of the vein will then probably only continue in or near the ravines. Every portion between two ravines will have most likely to be drained by a separate branch from the adit.

2d. An adit will allow work to be continued to the unusual depth of at least twenty-four hundred feet. Exploration and exploitation will be equally easy and inexpensive as the principal impediments to deep working will be removed.

3d. The removal of the ore, in particular, from the mines will be easy, expeditious, and cheap, since no more hoisting by application of steam-power will be required, but all the ore can be carried out on cars through the adit; the inclination of the lode of forty-five degrees will make the dumping of the ore into the adit-level convenient.

4th. The adit will give vent to a perpetual flow of water. It would be hazardous to undertake to calculate its amount. But if it is taken into consideration, that the water from a few adits above and back of the outcrops of the Comstock vein gives at present a sufficient flow for the wants of Virginia City and Gold Hill, and the adits to the Comstock mines at high levels furnish an additional supply for the requirements of all the reduction works near Virginia, Gold Hill, Silver City, and Johntown, a stream of greater

volume may be expected from the depth of nineteen hundred feet, and it will be considerably increased by the drainage of the country between the mouth of the adit and the Comstock vein. As there is a difference in elevation of about two hundred feet between the former and Carson River, the water may be made available for the erection of reduction works all along its course after it has left the adit. The cars carrying the ores from the mines may empty their contents immediately at the different mills, and thus the amounts of freight be avoided, which at the present contribute to render the reduction of the ores expensive. Steam-power on Carson River, as aforesaid, is cheaper than in the vicinity of the mines, but will scarcely be required to great extent on account of the water power of Carson River.

5th. A thorough ventilation of the mines will be effected by the adit, and the working thus accelerated and facilitated, and the decay of timbers diminished.

6th. A very important result of the construction of the adit would be the thorough exploration of the Comstock vein in those parts which up to the present have been unproductive. On all the mines between the Ophir and Gould and Curry, work has been discontinued and will probably not be resumed for a long time. North of the Ophir, where the character of the vein and the bold outcroppings on Cedar Hill appear, from analogy, to justify expectations of success, the explorations have always been very limited, and stock-

holders will soon be deterred from further investment by the expense required for deep explorations, if favorable indications at the present levels should not encourage them more than heretofore. The most unlucky portion of the whole Comstock vein has been American Flat, of which stock-speculation took a fatal hold. About one hundred locations were made all over the broad belt in which the several branches of the Comstock vein come to the surface, and quite as many "mines" opened. Far more than one million of dollars has been expended on these, but no decided result was obtained, on account of the scattered and superficial character of the work. The same outlay of money spent in a thorough and systematic exploration at one place would have sufficed for a thorough development, and the nature of that part of the lode would be known. But there is no prospect of such a work being undertaken. A complete discouragement followed suddenly the greatest excitement, and the mines have been almost entirely abandoned. Other reasons will retard the resumption of work, as, besides the expenditure which the adjustment of the numberless conflicting titles would require, the indications at upper levels are not encouraging. The vein is unusually wide, the diverging branches being about one thousand feet distant on the surface. The place where both walls descend parallel to the east, will therefore be at greater depth than in other portions of the vein, and exploring work ought to descend at once to about

eight hundred feet. The deep adit will not only explore all these unproductive parts of the vein at a depth of nineteen hundred feet, but also facilitate the examination of its entire body from that depth to the surface.

7th. Another advantage of the adit will be the exploration of the country from its mouth to the Comstock vein, which may possibly result in considerable profits. The line of the proposed adit is crossed by two belts of metalliferous veins, one to the east of the trachytic range, the other to the west of it. The former is at a short distance from the mouth of the tunnel, the other about two miles west of it. The latter will be cut about sixteen hundred feet below the surface. It contains several veins, among which the Monte Cristo, Occidental, and St. John are best known. The belt continues to the vicinity of Silver City. At many places the outcrops were found rich in gold and silver, and at present some ore from them is said to be worked with profit. These veins have never been thoroughly explored, but the appearance of their outcrops justifies the expectation of their ore-bearing character in depth.

The disadvantages of working the Comstock mines with the present system to considerably greater depth, compared with the great benefits which would result from the construction of a deep adit, are so self-evident as indeed to make the speedy execution of this work a question of vital importance to the future pro-

ductiveness of these mines. In the former case, the treasures buried in the unexplored depths of the vein will be valueless, in the other they will be a lasting source of wealth, for the owners of the mines, for the population of Washoe, and that portion of the community at large which depends more or less on the products of the Comstock vein. The amounts poured out by the latter to the imperfectly explored depth of five hundred feet, besides those which are still known to exist above this level, are such as to render insignificant the disbursement required for the execution of a work which will not only thoroughly explore the entire vein at a deep level, but allow the works to descend two thousand feet below their present lowest levels with comparative ease. The future yield of the mine, as argued before, is not to be expected from other concentrated bodies of rich ores, but from large accumulations of middle-grade and poor ores, which cannot be profitably extracted but after the completion of a deep adit. We consider its execution as the only possible way of securing the future productiveness and profitable working of the Comstock vein.